

Engineering Management
Field Project

**The Benefit of Lean Techniques Interfaced with
Modular Construction**

By

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Executive Summary:

The construction industry as a whole has not been keeping up with other industries in regards to its use and implementation of new technologies and techniques that can make the process better, faster, and more cost effective. On the whole there are two strategies that can be used to benefit the construction industry in numerous ways. The first thing that can be done is to implement Lean techniques. The other strategy that can be used is called modular construction. The tangible benefits of these two items can increase the quality of the product, reduce the cost of the final product, shorten the project duration, decrease waste, and increase productivity per man hour. One trade that has started to use these techniques is the glazing industry. I will focus on them specifically to highlight the benefits that have already been realized. This will hopefully encourage and show other trades the benefits of this approach.

Chapter 1: Introduction

According to some analyses the productivity in the construction industry has been declining for more than 30 years ("Improving Construction Efficiency & Productivity with Modular Construction" 2010). It means that for every hour a person works they are not accomplishing as much as they did over three decades ago. This is neither a healthy nor sustainable for the industry, construction companies, and for owners. Knowing that we in the construction industry are not getting better and utilizing the new techniques available, what can be done?

There are a number of proven techniques or strategies that can be used to help increase the productivity. The first technique that can be used is Lean. Lean is a technique in which you are continually improving and removing waste. This improvement may come in the form of quality or reduced time on a given task. As Lean is implemented areas that were not seen as needing attention before will now need attention. They might have seemed like the strong link in the production chain, but once the adjacent processes are improved it will then become the weak link. The goal of removing waste can come in many forms. Waste can be rework or time lost due to inefficiencies, quality issues, or poor communication.

The second technique that can be used is modular construction. Modular in the construction industry can be two different things. One way modular can be used is making the structure in multiple large parts that have all their finishes included in it. Once these large sections are made and delivered to the jobsite. Once on the jobsite the modules are attached together with minimal work needed to get the building operational.

The other way to use modular construction is to make smaller parts of the building that can be easily installed in the building. One example of this would be preassembling bathrooms with the plumbing run in the walls and then having them delivered to the site.

Not only does implementing one of these techniques prove to be beneficial for the company, but it can also be seen how they complement each other. The interfacing of these techniques will be examined.

There are a number of trades that are already utilizing some or both of these techniques. It is easy to see the benefits to the companies and trades that have started implementing this. They can get a lot more of their product installed on the building when compared to their competitors.

The glazing industry is one that has already started to use the modular technique. In the glazing industry it is called unitizing, and this means that panels are pre-manufactured with glass in them and then delivered out to the field. A panel will have all the parts and pieces already assembled upon reaching the field. Once the panels get to the field they can easily be hung on the building. This is much faster and efficient than the traditional technique which is called stick building. In stick building the glass, aluminum, facecaps, and seals are shipped out to the field and assembled on site.

Upon gaining some history of the glazing industry and spending some time in it, it can be easily seen that this particular industry has a history with both modular and non-modular construction as well as Lean and non-Lean techniques in manufacturing and installation it makes them a good case study to see all the benefits of both techniques.

When using both techniques together there can be a tangible impact on a number of parts of the project. Upon examination of the use and effects of Lean and modular construction there can be benefits in quality, finances, schedule time, waste, and productivity. Being able to quantify or explain the benefits is the goal of this case research.

Chapter 2: Literature Review

2.1 Lean Manufacturing

There is one book that stands above them all as a reference guide, a how to manual, and a list of case studies on Lean manufacturing and that book is “The Toyota Way”, by Jeffery K. Liker (2004). The author of the book wrote about what he learned from interviews and experiences at multiple Toyota factories around the world. This book describes all the different parts of Lean manufacturing. This is considered such a great resource because Toyota invented and refined Lean and its principles.

Included in “The Toyota Way” are the 14 principles that make up Lean. These principles lay out the foundation of Lean. It does an excellent job of explaining each principle and giving the examples of how Toyota uses them in their business. In addition to describing how they use the principles the book also has case studies illustrating how the principle affected their business.

The thoroughness of this book is one thing that makes it such a valuable resource. When working through each of the principles in this book Liker gives the full history or how each item came to be. In addition the evolution and change of each principle is tracked. Not only does this resource allow the reader to become familiar with the

principles, the way it is laid out makes it easy for anyone or company to have a road map to implementing them in their unique situation. The 14 principles covered in the “The Toyota Way” are:

1. Base Your Management Decisions on a Long-Term Philosophy, Even at the Expense of Short-Term Financial Goals
2. Create Continuous Process Flow to Bring Problems to the Surface
3. Use “Pull” Systems to Avoid Overproduction
4. Level Out the Workload (*Heijunka*)
5. Build a Culture of Stopping to Fix Problems, to Get Quality Right the First Time
6. Standardized Tasks Are the Foundation for Continuous Improvement and Employee Empowerment
7. Use Visual Control So No Problems are Hidden
8. Use Only Reliable, Thoroughly Tested Technology That Serves Your People and Processes
9. Grow Leaders Who Thoroughly Understand the Work, Like the Philosophy and Teach it to Others
10. Develop Exceptional People and Teams Who Follow Your Company’s Philosophy
11. Respect Your Extended Network of Partners and Suppliers by Challenging Them and Help them to Improve
12. Go and See for Yourself to Thoroughly Understand the Situation

13. Make Decision Slowly by Consensus, Thoroughly Considering All
Options; Implement Decisions Rapidly

14. Become a Learning Organization Through Relentless Reflection (*Hansei*)
and Continuous Improvement (*Kaizen*)

Another wonderful resource that was made available to was being able to interview Marc Butler. He is the Owner of J.R. Butler, Inc., a glass and glazing contractor located in Denver, Colorado. J.R. Butler manufactures and installs unitized curtain wall. Marc is a valuable resource because he uses Lean principles in his manufacturing facility. Not only that, but unitized curtain wall is modular construction. Since J.R. Butler, Inc. uses both Lean principles and modular construction they are an excellent resource. When Marc Butler started in the glazing industry (1994) he did not use either Lean or modular construction, so he is very familiar with the benefits of both and how they have changed his company. In addition to owning a company that utilizes the principles of Lean, he is also a Lean consultant that gets contracted out by other companies to help them implement Lean in their business.

When speaking with Marc (2012) it was amazing to hear how both Lean manufacturing and installation of pre-glazed curtain wall panels had changed his company. When he initially started in the business J.R. Butler, Inc. was started with the same model as most other glaziers. After a while Marc decided to start manufacturing pre-glazed curtain wall panels. This reduced the amount of time it took to close in a building dramatically. Not only was the schedule improved, but the quality of the finished product increased dramatically. “Manufacturing panels in a controlled environment instead of the field has allowed for increased quality because you are not

exposed to the elements and all the issues that come with being on a construction site.”

Marc Butler made this remark when discussing the merits of manufacturing in a shop instead of the field.

The next step for improving J.R. Butler, Inc. was to implement the Lean principles in their manufacturing process. Upon implementation of Lean in the process, there was again another noticeable increase in the quality of the product being produced, a typical result from that implementation. Additionally there was an increase in the speed that panels were manufactured. Marc captured that increase when he said, “Lean has reduced the amount of time that it takes to manufacture one panel by 50%”. Eric Cespedes, a shop supervisor at J.R. Butler said, “We would not be able to have this amount of capacity and quality through our shop without using Lean. I have been here through the transformation and it is not even recognizable.”

Another resource that showed the real world benefits of adding Lean to manufacturing was the article “Measuring the Success of Lean” by Steve Minter (2010). In this article he discusses and documents a company’s results as they make the transition to Lean. The implementation of Lean had a large measureable effect on the company. One of the tangible metrics was the length of the manufacturing cycle. They went from 15 days for a product down to three to five (Minter, 2010). That is a 66% reduction in time. Reductions such as this can completely change every aspect of business from its financials to its schedule.

2.2 Lean Construction

The construction industry as a whole has been slower to adopt new strategies and technologies that could help to benefit them. Lean is one of those things that could be used to help improve the construction industry. It has not been used very much at present due to a number of factors. One of those may be that “Lean thinking is new to many contractors, and adopting Lean construction requires a change of mindset with regard to current practices.” (Song et al. 2011). At this point from the literature found on the topic, Lean construction is something that has had limited real world applications. There have been some instances where Lean construction techniques have been tried and good results have been found.

One of the reasons that Lean may not yet have been adopted into mainstream construction is because Lean is thought of as a manufacturing strategy. However since Lean focuses on what add value to the product there must be a paradigm shift in the way that people think how Lean can be applied. Salem et. Al (2006) stated that construction is manufacturing on site as opposed to a fixed position manufacturing. They state that this then mean that in construction the value added activities occur at the job site as opposed to in a manufacturing facility. This means that the value added steps that normally occur in a controlled environment now happen outside with all the elements to deal with. The external factors such as weather, a large site, other trades, etc. make it difficult to control quality and schedule.

There are a number of reasons why Lean construction can be very useful. First is that the major goal of Lean is to reduce waste. In construction that can be material, time

spent walking, time spent looking for tools, double handling of material, or rework due to poor quality. The amount of waste in the construction industry was summed well by Song et al. (2011) “Industry research suggest that approximately 30%-35% of construction costs are wasted and do not add value for clients.” Imagine what could happen to the costs of project if the amount of waste was cut that drastically. Another way that waste was quantified in construction was discovered in an examination of public construction projects in Alberta. Jergeas (2009) concluded from his studies that the second largest portion of time spent next to working was walking. This could be looking for supplies, tools, people, etc. This is a prime example of waste in the construction industry and something that the implementation of Lean techniques could reduce.

One common issue in construction that causes the most problems, lost time, over budget, and schedule problems, is when rework has to be done. “Waste in our industry mainly comes from damage and rework” (Butler 2012). This is one major area where Lean can be of great use, because Lean is focused on reducing waste in the process.

Another benefit that could be observed from the implementation of Lean construction techniques could be an increase in quality. “Quality in construction is primarily related to product conformance.” (Salem et al. 2006). What this is referring to is the fact that construction of large buildings is typically a one of a kind product, as opposed to manufacturing where there is the mass production of a number of the same products. “Rework is a common practice because only one final product will be delivered” (Salem et al. 2006). That is why projects have a large number of specifications and requirements to ensure quality. When the quality is not satisfactory that is when rework will have to occur. Since rework is waste and indicates poor quality

the implementation of Lean would increase quality. That can potentially reduce rework, wasted money, and possibly costly lawsuits.

Another way in which Lean construction techniques and strategies can prove to be beneficial to all parties involved in a project is the impact that it will have on the budget. “Bae et al. argued that the key effect of using Lean construction methods for the purpose of sustainability positively affects the economic dimension by reducing upfront costs, operating costs, and resources saving, and improving performance capability.” (Nahmens et al. 2012). This economic benefit that is obtained through reduction of waste, which is the main goal of Lean, continues to manifest itself in different ways through the process.

2.3 Modular Construction

Modular construction is a technique that involves using a controlled manufacturing process and location to fabricate a component of the building. After those parts are manufactured they are then sent out to the jobsite to be installed on the building. Through the years that different construction industries and trades have been making modular parts to buildings there have been a number of tangible benefits. Those benefits have come in the form of increased productivity, higher quality, shorter project durations, and reduced waste.

Productivity in the construction industry has been lagging behind other industries. It was stated well in the article called “Improving Construction Efficiency & Productivity with Modular Construction” (“Improving Construction Efficiency & Productivity with Modular Construction” 2010) saying that, “U.S. industries have experienced almost continuous productivity growth for the past several decades. The one anomaly has been

the construction industry, for which overall productivity has declined from 1995 to 2001.” This may be due to any number of reasons. It could range from the construction industry being slow to adopt new techniques to or not having to compete with other countries that may be performing a certain task more efficiently than the standard method used by contractors in the United States. A superintendent that has installed thousands of modular pieces in the field had this to say about increased productivity, “Having pre-glazed panels allows us to blow our competitors out of the water when it comes to speed and quality of the product we install.” (Mestas, 2013).

Research also shows that being able to manufacture products in a controlled environment will help to increase the quality. The quality happens due to the elimination of a number of the variable that can cause quality issues. Some of those are weather, site conditions, and uncomfortable or awkward working positions. Performing these tasks repeatedly in a manufacturing facility will allow for the tasks to become standardized in a controlled environment where more ergonomic and comfortable body positioning can be obtained. This will allow for greater controls and increased productivity.

“Manufacturing building components off-site provides for more controlled conditions and allows for improved quality and precision in the fabrication of the component.” (“Improving Construction Efficiency & Productivity with Modular Construction” 2010).

2.4 Literature Review Summary

In summary Lean manufacturing techniques can drastically change the landscape within a company that they implemented in. Toyota has pioneered the way and

developed a great system. The benefits of Lean can reduce manufacturing times and increase quality; giving many benefits to all parties involved.

The use of Lean in construction has been slow to be adopted because of what people perceive it to be and assume that it has use only in the manufacturing facility. There are many ways that Lean can be practically implemented in the field and can save time and money while reducing waste and increasing quality.

Modular construction is an easy step that many different traits can take to increase their productivity to help them keep up with other industrial trends. Along with productivity the added increase in quality from making the product in a controlled environment will allow for increased quality and decreased rework.

Chapter 3: Research Procedure

3.1 Online

Researching online provides almost limitless amounts of information to read through and digest. Narrowing it down to information that would be useful in this application was the challenge. When refining the search criteria date was the easy first item to look at per the requirements of the project. After that the decision had to be made as to what type of articles or journal articles would be the best fit for what the given topics were. It was decided that only published works would be used, articles written on websites would not be used. The resource that provided the most and best published articles was the search engines provided by the University of Kansas.

When a review the different articles one of the items that seemed important was to find actual studies that had been performed. Also people giving their accounts from industry experience. Hypothetical articles with guesses at what could happen were avoided. This would hopefully give a more concrete case for the implementation of Lean and modular construction where applicable in the construction industry in the United States of America.

3.2 Printed Literature

The number of printed resources that are available that combine both Lean and modular construction are very limited. The assumption behind that would be because those two items are not interfaced frequently in practice. This resulted in being able to find books that either talked about Lean or about modular, but not both. As previously discussed “The Toyota Way” is the book that has laid the groundwork what Lean is and how to implement it. There are a few other books that discuss Lean, but none to the depth of the “Toyota Way”.

Modular construction is a topic that has been discussed and what impact it can have on the industry. It is not completely new idea, just look at double wide trailers. They are made in a factory and in multiple parts then assembled on site. The books like “Refabricating Architecture” written in recent are outlining a case for why we need to change the way that we are building buildings in America.

3.3 In Person Interview

Being able to interact with and question someone that has used and implement both Lean and modular construction in their company was a valuable resource. This is

the best case study and proof that when implementing both of these strategies there can be substantial and tangible results. The resource that Marc Butler provided was immense due to all of his real world hands on experience. While speaking with him being able to see all the principles applied and how they work really puts a picture to the words. Additionally an interview was conducted with a supervisor in the shop and a superintendent in the field, both of whom work for J.R. Butler. They were valuable resources because they have firsthand experience with Lean and modular construction.

Much of the information that was provided J.R. Butler was among the most useful. This is due in part to them being a perfect case study for the interfacing of Lean techniques and modular construction. Marc Butler talks about how without using these different techniques together a company the size of J.R. Butler could not be competing with some of the larger international glazing contractors (Butler, 2013). One of the superintendents, Felix Mestas, expressed frustration to me about how the other trades that tie into the glazing systems and have to get done first can't get far enough ahead of him and he keeps catching them (Mestas, 2013). This showcases how modular construction allows the pace of work to be much faster than traditional construction methods.

3.4 Personal Observations

As a former member of J.R. Butler the privilege of seeing many of these practices put into place was an invaluable resource. Additionally, being able to see glazing done the old way and compare it with Lean and Modular Construction techniques that are being used now show quite an impressive difference. In the construction industry it is now a high pressure world that has compressed schedules and higher demands for quality

something needs to change. Getting the building “closed in” or water tight is a huge milestone and glazing is normally the hold up. Using modular construction J.R. Butler finds themselves waiting on other trades. That causes a very large paradigm shift on jobs where that happens. Being able to perform every step in the process at J.R. Butler allows for the privilege of becoming intimately familiar with how it all works together.

In the shop it all boils down to getting more panels out faster with fewer errors. All of this makes Lean the perfect fit. It has been proven many times to be a great tool for increasing both productivity and quality. Lean comes through on both of those. The quality checks at every station catches many errors, and the efficiency of using Kanban (Liker, 2004), a visual system indicating when parts are needed at the next station, and other lean techniques does great things for productivity.

In the field when you compare stick building a curtain wall system to installing pre-glazed panels, there is really no comparison. Metrics used to measure efficiency for glazing is square feet per day. Traditional stick building you can achieve around 800 square feet per day. Compare that to pre-glazed panels where you can get over 2,000 square feet per day.

In the end it really is a business and comes down to dollars. Being able to get more done in less time decreases man hours per unit of measure. An example of reduction of man hours per panel looks like this, in stick built curtain wall each panel will consume around 22 man hours. Contrast that with 16 hours per panel in pre-glazed curtain wall the difference is clear. The current average labor rate for a glazier is \$36 per hour. A savings of 6 hours per panel amounts to a monetary gain of \$216. On a small

job with just 100 panels that still amounts to a savings of \$21,600 or 27.2% (Douthit, 2013). That allows a company to make a higher profit, pay higher wages, or be the low bid if the situation calls for it. The more jobs a company can procure the more stable the company which is beneficial for the owners and employees.

Chapter 4: Results as Applicable to the Glazing Industry

4.1 Impact on Quality

Increased quality is one thing that seems to be a result of both modular construction and Lean principles. The following ways highlight the impact they both have.

Modular construction typically involves building a piece of the building that would normally be built in the field and constructing it at a manufacturing facility. “A manufacturing environment allows you to look at every piece in a controlled environment to make sure it is there and done right. There is no comparison in quality.” (Butler 2012). When dealing with glass and critical water seals the ability to put those together in controlled environment helps immensely. That environment provides relief from the elements, wind, and dust. Also, the work is being done in an ergonomic position. When putting together glass curtain wall in the field the glazier is frequently in awkward positions that may lead to imperfect seals around the glass.

One of major benefits of using the Lean principles increased quality. Lean focuses on doing tasks only one, or getting quality right the first time. Another core principle of Lean is that the next person in the process provides quality control for the task previous to them. This allows multiple people to check the processes and hopefully

reducing the amount of rework that has to be done. Contrast the number of people getting to check each step to field installation where only one other person may see a particular item. The case for modularizing as many pieces as possible seems fairly straight forward.

4.2 Impact on Finances

The impact on finances has benefits to both the owner of the buildings and the company performing the work. If a company uses Lean techniques to reduce the amount of rework they have to do and it decreases their costs make certain items that can then increase the profit margin. Additionally if it decreases their schedule the companies will have to pay for less man hours to accomplish the same amount of work. If the contractors choose to do so they can use the reduced costs and pass them on the owner. Passing those cost savings on may allow the contractor to be more competitive and secure more jobs. Either way it seems like the financial benefits for the contractor seem to there if Lean and modular strategies are implemented.

The glazing industry measures and compares costs in terms of dollars per square foot. This is done because glazing is typically bid by the square foot. The exact costs are specific and guarded from company to company, but general numbers can be given. When looking at stick built curtain wall, depending on the system, glass infill, and height, prices will range from \$105-\$130 per square foot. In contrast pre-glazed curtainwall will range around \$75-\$85 per square foot. On a job where there is 50,000 square feet of glazing or more those numbers can really add up.

4.3 Reduced Schedule Time

Lean and modular has helped to reduce the amount of time it takes to build the products and install them in the field. With the advent of design build and the compression of schedules that has resulted contractors need to find ways to get to the field with their product and complete the installation quicker. Using Lean manufacturing and reducing the wasted time and steps allows product to get made faster. When glazing curtain wall the traditional method is called stick building. This entail bringing all the glass, aluminum, and seals to the field and installing them in place. The way to reduce the schedule by modularizing curtain wall it call unitizing. “Unitizing provides a higher quality product and allows you to install the product in the field 65% faster than stick building.” (Butler 2012).

The pre-glazed panels offer a great reduction in the amount of time that a crew can spend on a job site. Slaughter (1999) looked at the production rates for both traditionally built curtain wall and pre-glazed curtain wall and compared the two through a simulation. What she saw was that by using the pre-glazed units the amount of time spend installing the panels could be reduced by approximately 40.1%. This is a large shift in the traditional paradigm of building construction.

4.4 Decreased Waste

When manufacturing unitized curtain wall in shop there is much waste that can be avoided that might have occurred in the field while stick building curtain wall. One of the waste item is the aluminum pieces that are used to support the glass. When using Lean techniques and planning for how the aluminum will be cut and when it is needed

can achieve efficiencies up to 98% to 99%. For an average sized commercial glazing job there will be approximately 40,000 square feet of glazing. This amounts to about \$125,000 worth of aluminum. If the aluminum is not optimized and cut in that manner efficiencies can run as low as 92%. This difference can add up to around \$10,000 of extra cost or waste. Also, certain types of silicone that would typically be field applied using single use tubes can now be applied using different applicators that will reduce the amount of excess silicone purchased.

Lean also views rework as waste. So being able to test unitized panels and have extra quality control that the shop provides reduces that amount of rework. Reduced material uses and rework is considered waste reduction.

4.5 Summary of Application to the Glazing Industry

When using Lean manufacturing and construction techniques married with modular construction in the glazing industry the result is tangible and beneficial for all parties involved. With reduced waste there is less cost in materials and rework. Decreased schedule time means that the building envelope can get closed in quicker and projects can get to the field quicker. The resulting increase in quality will help deliver a better product in the end with a much smaller chance of failing. This comes as a result of Lean producing consistent products. Finally less rework leads to decreased costs which can be passed on to the company or owner of the project. There seems to be no reason why other trades would not pursue the same course.

Chapter 5: Suggestions for Additional Work

Further investigation of how Lean manufacturing, Lean construction, and modular construction interface should be pursued for the sake of the construction industry in the United States. The glazing industry is one easy area to look at how it can help. Especially since there are companies that don't use any of the topics discussed. Additional research should be pursued to see how other trades can use the methods described. Special attention should be given to trades that tend to be on the critical path for building construction. One milestone in building construction is getting a building "dry" which mean that it is protected from the element. Glaziers are normally the trade that does that task. There are other trades that bottleneck the schedule on every project. The best way to conduct additional work would to be from the inside of these companies so they can see how it would help. Additional work should be performed with a willing company and give them specific suggestions so they can see they tangible results.

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Appendix A: Questionnaire

1. What results have you seen in relation to quality from implementing Lean in the manufacturing facility?
2. What results have you seen in relation to production rates from implementing Lean in the manufacturing facility?
3. What results have you seen in relation to costs from implementing Lean in the manufacturing facility?
4. What results have you seen in relation to quality from implementing Lean in the field?
5. What results have you seen in relation to production rates from implementing Lean in the field?
6. What results have you seen in relation to costs from implementing Lean in the field?
7. What results have you seen from using pre-glazed panels when compared to traditional stick built curtain wall?
8. What has the combination of Lean and modular construction techniques done the competitiveness of the company?